A VACUUM RADIOMICROMETER.

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Radiometers having vanes weighing less than 10 mg are easily affected by earth tremors, so that for general work it is not advisable to reduce the weight much below this amount. Such a moving system is of course not very sensitive for a short period. With a fiber suspension of such a diameter that the maximum deflection is reached in 15 to 20 seconds, the sensitiveness is not much greater than 6 to 8 cm deflection per square millimeter surface exposed, the candle and scale each being at a distance of 1 meter. With this sensitiveness, however, the readings are always perfectly reliable, and such an instrument is to be preferred to a more sensitive one which gives longer deflections, but which, on account of lightness of the vane, is more affected by earth tremors and temperature changes.

On the other hand, in the radiomicrometer of Boys, the period is governed by the magnetic moment of the moving parts, rather than by the torsion of the fiber suspension, and in nearly all instruments thus far described it is much shorter than that of the type of radiometer just mentioned. Boys' radiomicrometer had a sensitiveness of only about 1 cm per sq. mm (candle and scale at 1 meter) for a suspension weighing 32 mg and a period of 10 seconds. He used a window to prevent air currents. This instrument has received but scant attention since it was first described by Boys, although Paschen[1] attempted to improve the instrument; but for the best junctions (out of perhaps 50) he could obtain only about 3 times the sensitiveness obtained by Boys, with a period of about 40 seconds. He then turned his attention to the bolometer with his well-known success.

[1] Paschen: Ann. der Phys. **48**, p. 275; 1893.

The bolometer, however, with its delicate galvanometer requires an elaborate installation, and needs so much attention that the investigator's time is occupied principally with the care of the instrument, which should be a secondary matter in any work.

A great many radiometric investigations do not require the highest attainable sensitiveness and in such cases a radiometer or a radiomicrometer is a convenient laboratory accessory. The thermopile also has its place, but with this instrument heat conduction, local electromotive forces, etc., must be contended with.

The present study of the radiomicrometer was undertaken with the purpose of combining it with the radiometer, in order to develop more energy in the suspended system. The chief difficulty encountered in this combination is to obtain systems which are free from magnetic material. Diamagnetism also plays an important part in this form of thermojunction so that the radiometer effect is masked by the magnetic effect of the coil.

In the radiomicrometer proper the Bi-Sb junction hangs vertically at the axis of the system and therefore is not so seriously affected by its diamagnetism; hence, if the magnet is not too strong a fairly sensitive instrument is obtainable. Since a window improves its steadiness, the whole may as well be in a vacuum which eliminates heat conduction, as is well known for thermopiles. In this way the sensitiveness of a certain system, to be described presently, was increased by about 70 per cent. By using No. 40 copper wire and bits of Bi-Sb, soldered with Wood's alloy, it is possible to reduce the weight to 10 mg, which, as already mentioned, is a convenient weight. The period of such a system will be much less than that of the radiometer of similar sensitiveness.

Before describing the present instrument it will not be out of place to mention some facts concerning tests of sensitiveness of instruments. In previously described instruments no mention is made of the shielding of the thermojunctions from radiation other than that which falls directly upon the vane. The test of sensitiveness is hence not necessarily a fair one, since reflection from the walls has an enormous effect in increasing the sensitiveness. In fact, the measured sensitiveness may be twice the true value.

In the present instrument (Fig. 1), which is a design for a radiometer-radiomicrometer or a combination of the two, the receiv-

ing surface is directly behind the window, which is covered with an adjustable slit the length of the vane. In this manner no radiation reaches the walls of the instrument, which are black.

The bismuth for one part of the junction was obtained by melting

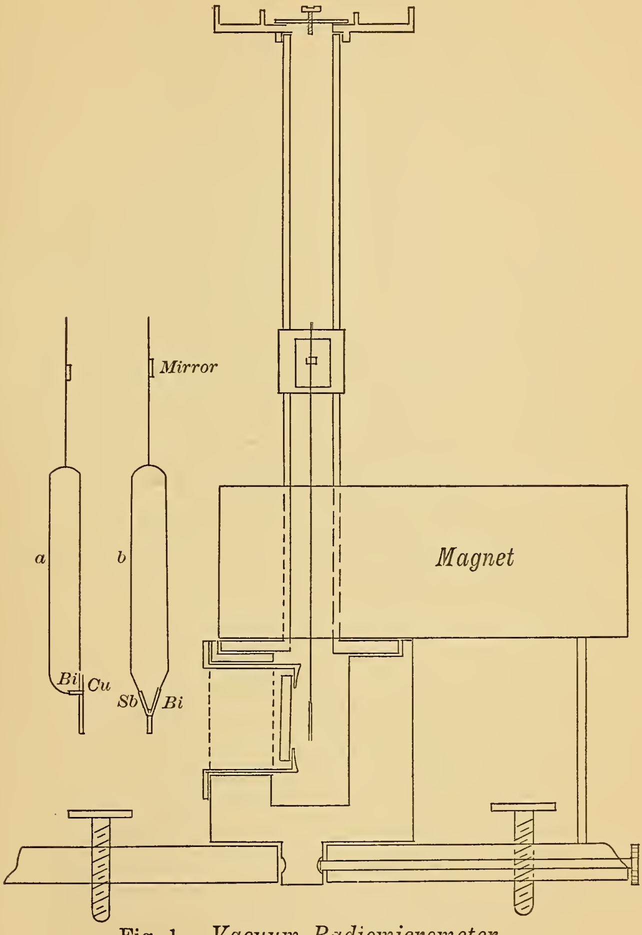

Fig. 1. *Vacuum Radiomicrometer*
Side View

the metal between glass or iron plates, which were then pressed together. These thin plates were then cut into strips from 0.15 to 0.2 mm wide. The antimony part of the junction was split from a large, well-crystallized piece of the metal. These pieces could not

be obtained quite so thin as the bismuth. The Bi and Sb pieces were then soldered, in the form of a Y, to a thin sheet of copper. This is not so good as to have the pieces more nearly parallel, since in the latter case the diamagnetic moment is reduced. The dimensions of the Bi and Sb pieces were about $3.5 \times 0.2 \times 0.1$ mm. The length of the copper loop of No. 40 wire was 4.5 cm. The area of the thin copper vane was 3 sq. mm. It was blackened by covering it with a little canada balsam, upon which was dusted fine copper oxide. The weight of the complete loop was less than 10 mg. The magnet was taken from a Weston ammeter. It was used without pole pieces, since the latter caused too much damping. The top was covered with the bulb of a thistle-tube, the mouth of which was ground flat. The heavy metal base of the radiomicrometer is of swedish iron. The narrow vertical tube is of brass. All the joints are made with Khotinsky cement, except the one at the top and the one containing the support of the rock salt window. The top seal is made with mercury. A torsion head is provided to bring the mirror to any desired position. The loop for the radiometer-radiomicrometer is shown in Fig. 1, *a*. The bismuth is about $2 \times 0.15 \times 0.1$ mm, soldered to a thin sheet of copper $8 \times 0.6 \times 0.1$ mm. In one case a sheet of mica of the same area was used and extended below the copper sheet which was then only 2 mm long. This loop also weighed less than 10 mg. As a radiometer the time required for a maximum deflection was 25 seconds, and its sensitiveness was about 3 to 4 cm per sq. mm area of vane, using a Geryk pump vacuum which was not high enough for maximum radiometer sensitiveness. This same loop used as a radiomicrometer had a sensitiveness of about 5 cm deflection per sq. mm area of vane, while its maximum deflection was reached in 8 seconds. The combination of these two was no better than the radiomicrometer, simply owing to the fact that the periods were different and the magnetic moment of the radiomicrometer masked the radiometer effect. Another loop twice as heavy had a half period (time of maximum steady deflection) of 5 seconds when used either as a radiometer or radiomicrometer. The actual sensitiveness was much lower than in the preceding loops. In this case the radiometer contributed only 15 per cent to the total deflection, while the sensitiveness of the

loop when used as a radiomicrometer was increased 50 per cent by placing it in a vacuum.[2]

In Fig. 1, *b*, is shown the loop for the radiomicrometer. The dimension of the Bi–Sb junction are indicated above. Its half period in air was 20 to 25 seconds and the deflections were 3.6 cm per sq. mm, for candle and scale at one meter. On exhausting the instrument with a Geryk pump the half period decreased to 12 or 14 seconds, while the deflection increased to 5.5 and 6 cm per sq. mm (70 per cent) of exposed area of vane; as the pumping progressed the sensitiveness increased. The result as a whole indicates that the weight of the moving coil can be reduced at least to one-third of those previously described and that its sensitiveness can be increased by at least 70 per cent by placing the loop in a vacuum. Since a window is used to increase the steadiness, the vacuum is no drawback, while, as already stated, it can be given a shorter period than a type of radiometer having a heavy vane.

The purpose in describing this form of instrument is not so much to show the sensitiveness of the present one as to indicate directions in which further improvements are possible. On account of the difficulties in preparing a nonmagnetic loop there is still much room for improvement in combining the radiometer and the radiomicrometer. For detecting electrical waves the system can be made still lighter and the heating arrangement can be brought close to the junction.

In conclusion, the fact may be emphasized that in the present test of sensitiveness only that radiation which passed through a slit and fell directly upon the vane was measured. If this precaution had not been taken the results would have been much higher and as in some other cases would have been misleading.

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[2] The method of testing is as follows: The radiomicrometer effect is first found in air. It is then exhausted and the deflection again noticed. The magnet is then removed and the deflection obtained is due to the radiometer effect. The magnet must, of course, be placed so that the radiomicrometer deflection is in the same direction as that of the radiometer.

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